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28822

-Technical Report-

Fixed Heel Point (FHP) Accommodation Model Verification & Validation (V&V) Plan - Rev A

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US Army TARDEC, Warren, MI

UNCLASSIFIED: Distribution Statement A
Approved for Public Release

23 January 2017

U.S. Army Tank Automotive Research,
Development, and Engineering Center
Detroit Arsenal
Warren, Michigan 48397-5000

UNCLASSIFIED

REPORT DOCUMENTATION PAGE

Form Approved OMB No. 0704-0188

1. REPORT DATE ***03/07.2014***
23-January-2017

2. REPORT TYPE
V&V Plan

3. DATES COVERED ***(From - To)***
January 2014 – January 2017

4. TITLE AND SUBTITLE

Fixed Heel Point (FHP) Accommodation Model Verification & Validation (V&V) Plan – Rev A

5a. CONTRACT NUMBER
N/A

5b. GRANT NUMBER
N/A

5c. PROGRAM ELEMENT NUMBER
N/A

6. AUTHOR(S)

Gale L. Zielinski and Frank J. Huston II

5d. PROJECT NUMBER
N/A

5e. TASK NUMBER
N/A

5f. WORK UNIT NUMBER
N/A

7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) AND ADDRESS(ES)

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MS 207
6501 E. 11 Mile Road, Warren, MI 48397-5000

8. PERFORMING ORGANIZATION REPORT NUMBER

N/A

9. SPONSORING / MONITORING AGENCY NAME(S) AND ADDRESS(ES)

N/A

10. SPONSOR/MONITOR'S ACRONYM(S)
N/A

11. SPONSOR/MONITOR'S REPORT NUMBER(S) N/A

12. DISTRIBUTION / AVAILABILITY STATEMENT

UNCLASSIFIED: Distribution Statement A. Approved for Public Release, Unlimited Distribution

13. SUPPLEMENTARY NOTES
N/A

14. ABSTRACT
Military ground vehicles are currently designed using requirements from MIL-STD-1472G, the *Department of Defense Design Criteria Standard Human Engineering*. The MIL-STD, however, is difficult for designers to apply properly because it is often open to interpretation. Easy to use Computer-Aided Design (CAD) tools, such as accommodation models, are needed by the ground vehicle community, to address this issue (Zielinski, Huston II, Kozycki, Kouba, & Wodzinski, 2015). The first in a series of accommodation models being created is the fixed heel point (FHP) accommodation model. The V&V is intended to build confidence in the FHP accommodation model for use in ground vehicle design. The model is applicable to ground vehicles where driving is controlled via a conventional accelerator pedal and steering wheel configuration or in a vehicle workstation that requires the crew to interact with vehicle controls and displays using hands, horizontal directed vision, and adjustable seats (Zerehsaz, Ebert, & Reed, 2014). The FHP model is intended to provide the composite boundaries representing the body of the defined target Soldier population, including posture prediction. The boundaries defined provide required space claim for the encumbered Soldier's helmet, eyes, torso, and knees. Clearances between the Soldier and surrounding interior vehicle surfaces have been added per MIL-STD- 1472G (e.g. head clearance required from head (helmet) to vehicle roof line and thigh clearance to the steering wheel).

15. SUBJECT TERMS
Fixed Heel Point (FHP), accommodation model, occupant work space, central 90% of the Soldier population, encumbrance, posture and position, verification and validation, computer aided design (CAD)

16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT	18. NUMBER OF PAGES	19a. NAME OF RESPONSIBLE PERSON
					Gale L. Zielinski
a. REPORT	b. ABSTRACT	c. THIS PAGE	UNLIMITED	26	19b. TELEPHONE NUMBER *(include area code)*
UNLIMITED	UNLIMITED	UNLIMITED			(586) 282-5287

Standard Form 298 (Rev. 8-98)
Prescribed by ANSI Std. Z39.18

TANK-AUTOMOTIVE RESEARCH
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23 January 2016

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By

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RECORD OF CHANGES

Version No.	Date	Changes
Initial Release	2 February 2016	
Rev A	17 January 2017	Editorial and updated Verification and Validation Test Plans

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ACKNOWLEDGEMENTS

The authors would like to acknowledge the contributions of the following individuals for their assistance in the creation of this report:

Cheryl A. Burns, Army Research Laboratory Human Research and Engineering Directorate (ARL HRED)

Richard W. Kozycki (ARL HRED)

Matthew P. Reed, PhD, University of Michigan Transportation Research Institute (UMTRI)

1. V&V PLAN EXECUTIVE SUMMARY

Military ground vehicles are currently designed using requirements from MIL-STD-1472G, the *Department of Defense Design Criteria Standard: Human Engineering*. The MIL-STD, however, is difficult for designers to apply properly because it is often open to interpretation. Easy to use Computer-Aided Design (CAD) tools are needed by the ground vehicle community to address this issue. The CAD tools being developed are called accommodation models. Accommodation models are constructed from 3D empirical data for a given seating configuration to provide population workspace boundaries that include the effects of both anthropometry and posture (Zielinski, Huston II, Kozycki, Kouba, & Wodzinski, 2015). The verification and validation (V&V) effort is intended to build confidence in accommodation models for use in ground vehicle design.

The first in a series of accommodation models being created is the fixed heel point (FHP) accommodation model. That model, described in this V&V plan, is applicable to ground vehicles where driving is controlled via a conventional accelerator pedal and steering wheel configuration or in a vehicle workstation that requires the crew to interact with vehicle controls and displays using hands, horizontal directed vision, and adjustable seats (Zerehsaz, Ebert, & Reed, 2014). The FHP model is intended to provide the composite boundaries representing the body of the defined target Soldier population, including posture prediction. The boundaries defined include the required space and seat adjustments needed for the encumbered Soldiers' helmet, eyes, torso, and knees. Clearances between the Soldier and surrounding interior vehicle surfaces have been added per MIL-STD-1472G (e.g. head clearance required from head (helmet) to vehicle roof line and thigh clearance to the steering wheel). The FHP model is a statistical model created utilizing data collected in the *Seated Soldier Study* (Reed & Ebert, 2013) completed by the University of Michigan Transportation Research Institute (UMTRI). The original model, as provided by UMTRI, consists of a Microsoft Excel workbook. The CAD version of the model was created using PTC Creo® 3D CAD software and is a stand-alone geometric reproduction of the output found in the UMTRI Microsoft Excel spreadsheet.

This CAD accommodation model can be applied early in the vehicle design process to ensure accommodation requirements are met and help explore possible design tradeoffs when conflicts with other design parameters exist. Vehicle designers can use the FHP accommodation model for the following scenarios: 1) during the concept and design phase of new acquisition programs, 2) while upgrading existing ground vehicle platforms, and 3) for assessing a commercial off the shelf (COTS) system. Human factors engineers could benefit by working with vehicle designers to perform virtual assessments in CAD when there is not enough time and/or funding to translate vehicle models into assessment software compatible formats and perform detailed human figure modeling.

The FHP CAD accommodation model V&V effort will produce a V&V Report that captures the results of the activities completed per this V&V Plan. Any areas that do not meet the defined

V&V acceptability requirements will be reviewed and a path forward will be provided to correct the issue. The V&V Report will be signed off by the developers and V&V SMEs.

2. PROBLEM STATEMENT

Military ground vehicles are currently designed using requirements from MIL-STD-1472G, the *Department of Defense Design Criteria Standard: Human Engineering*. The requirement to accommodate the central 90% of the Soldier population in which the fully encumbered Soldier can sit safely and comfortably while performing all required functions, including driving, requires multivariate analysis methods so that both Soldier anthropometry and posture can be considered (DoD, 2012). MIL-STD-1472G is often open to interpretation and is therefore difficult for designers to apply consistently. Easy to use, valid design tools and procedures based on these methods are needed to effectively design vehicle workstations. The chosen tools are Computer-Aided Design (CAD) based accommodation models, adapted for Soldiers in military ground vehicles, that directly parallel long-standing Society of Automotive Engineers (SAE) recommended practices used in the commercial automotive and truck domains (Zielinski, Huston II, Kozycki, Kouba, & Wodzinski, 2015).

2.1 Intended Use

The fixed heel point (FHP) accommodation model described in this verification and validation (V&V) plan is applicable to ground vehicles where driving is controlled via a conventional accelerator pedal and steering wheel configuration as is the case with various Army tactical wheeled vehicles. Because of this, the FHP accommodation model may also be used in workstations that require the crew to interact with vehicle controls and displays using hands, horizontal directed vision, and adjustable seats (Zerehsaz, Ebert, & Reed, 2014).

The FHP model is intended to provide the composite boundaries representing the body of the defined target encumbered Soldier population, including the effects of body size, vehicle layout, and Soldier protective equipment and gear. The boundaries defined include the required space and seat adjustments needed for the encumbered Soldiers' helmet, eyes, torso, and knees. Clearances between the Soldier and surrounding interior vehicle surfaces have been added per MIL-STD- 1472G (e.g. head clearance required from head (helmet) to vehicle roof line and thigh clearance to the steering wheel).

2.2 M&S Overview

The FHP model is a statistical model created utilizing data collected in the *Seated Soldier Study* (Reed & Ebert, 2013) completed by the University of Michigan Transportation Research Institute (UMTRI). The original model, as provided by UMTRI, consists of a Microsoft Excel workbook. The CAD version of the model was created using PTC Creo® 3D CAD software and is a stand-alone geometric reproduction of the output found in the UMTRI Microsoft Excel spreadsheet.

Model inputs include the definition of the target driver population (a subset of the Army Anthropometric Survey (ANSUR) II), the ensemble (clothing and equipment worn by the Soldier), the desired level of accommodation (for example, 90%), the nominal location of the steering wheel, and the target population gender mix. The ensemble is selectable as either Personal Protective Equipment (PPE) which includes the Improved Outer Tactical Vest (IOTV) or Encumbered (ENC) which includes the PPE and Rifleman Ensemble, both of which are defined in the *Seated Soldier Study*. Ideally the level of accommodation will be set at the central 90% of the target design population to be consistent with MIL-STD-1472G requirements. The only vehicle input to the model is the location of the steering wheel, as determined by the Steering Wheel Point (SWP) (Zielinski et al., 2015).

The CAD accommodation model represents the posture and position variability for the entire selected Soldier population (e.g. central 90% of Soldier population, 85% male). The model can guide vehicle designers in creating an optimized work space for the occupant. The CAD accommodation model, along with additional added space claims for human factors, can be used to visualize MIL-STD-1472G requirements. This eliminates the concern of the MIL-STD being interpreted differently by vehicle designers when creating the occupant workspace (Zielinski et al., 2015).

2.3 M&S Application

The use of the FHP accommodation model provides the opportunity to apply Human Systems Integration (HSI) very early in the acquisition process. The model could be utilized during the Material Solution Analysis Phase prior to Milestone (MS)A and up through and including MSB. Past programs have not actively engaged HSI until MSB or the Engineering Manufacturing and Development (EMD) Phase, resulting in significant design and cost changes.

This CAD accommodation model can be used to explore possible design tradeoffs when conflicts with other design parameters exist. Vehicle designers can use the FHP accommodation model for the following scenarios: 1) during the concept and design phase of new acquisition programs, 2) while upgrading existing ground vehicle platforms, and 3) for assessing a commercial off the shelf (COTS) system. Human factors engineers could benefit by working with vehicle designers to perform virtual assessments in CAD when there is not enough time and/or funding to translate vehicle models into assessment software compatible formats and perform detailed human figure modeling.

2.3.1 Model Origin

The Accelerator Heel Point (AHP) is the origin for the FHP accommodation CAD model. As defined in SAE J1100 (2009), Figure 1, the AHP is the location where the heel of the driver’s shoe contacts the floor of the vehicle assuming an undepressed accelerator pedal, compressed floor covering, and an angle of 87 degrees between the lower leg and foot.

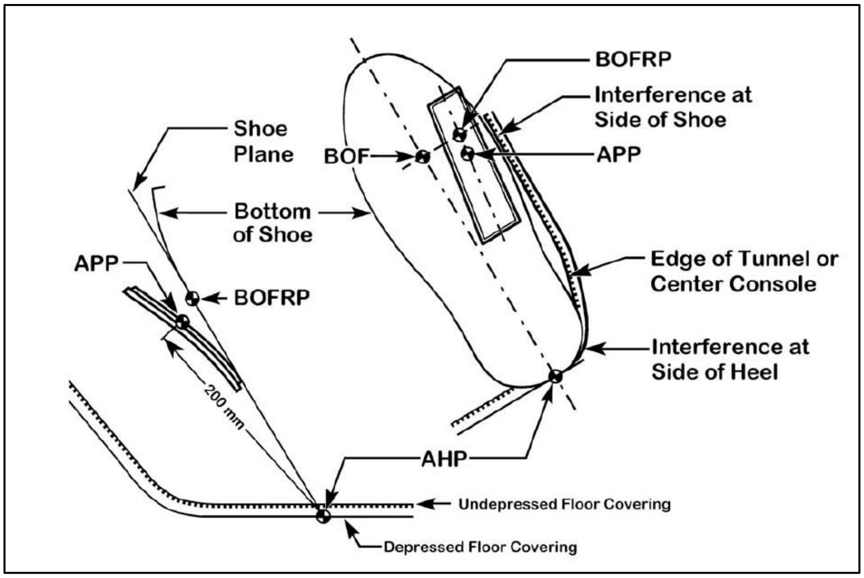

Figure 1: Definition of AHP from SAE J1100 (Figure 10)

2.3.2 Model Inputs

The FHP accommodation model requires five inputs; these are listed in Table 1 below.

Table 1: FHP Accommodation Model Inputs

Target Accommodation	The percentage of the Soldier population to be accommodated in the design. Those Soldiers not accommodated are evenly split between the smaller and larger extremes of the population. In MIL-STD-1472G, the accommodation target has been set at the central 90%. (DoD, 2012).
Fraction Male	The percentage of males in the defined Soldier population.
Encumbrance	Soldier clothing and equipment available for selection in the model: • [1]PPE = ACU + IOTV + ACH • [2]ENC = PPE + Rifleman Ensemble
Steering Wheel Point (SWP)	The SWP is the effective center of the steering wheel and is reported in horizontal and vertical components with respect to the AHP (Reed, 2005).
Hydration Pack Relief Availability	A seatback with hydration pack relief can fully accommodate a Soldier's hydration pack such that the Soldier's position in the seat is the same regardless of wearing a hydration pack. The following selection will be available in the model: • Yes • No
Human Accommodation Reference Point (HARP) Measurement Device	The expected distribution of driver-selected seat positions relative to the AHP is predicted based on the seat design HARP measurement tool selected. The two options of seat design HARP measurement tools are the Society of Automotive Engineers (SAE) J826 H-point manikin and Seat Index Point Tool (SIPT) (Reed &

	Ebert, 2014). The following selection will be available in the model: • J826 • SIP

[1] Personal Protective Equipment (PPE), Advanced Combat Uniform (ACU), Improved Outer Tactical Vest (IOTV) that included Enhanced Small Arms Protective Insert (ESAPI) plates, Enhanced Side Ballistic Inserts (ESBI), and Advanced Combat Helmet (ACH).
[2] Encumbered (ENC), Rifleman Ensemble defined in the Soldier Load Configurations in Ground Vehicles (McNamara, 2012) and Seated Soldier Study (Reed et al, 2013).

2.3.3 Model Outputs – Based on UMTRI Seated Soldier Study

The primary model outputs include Soldier population boundaries and preferred boundary manikin posture and position information for the vehicle designer to utilize when creating or assessing an occupant workspace. Model outputs are described below in Table 2 and shown in Figure 2.

Table 2: FHP Accommodation Model Outputs and Definitions based on Seated Soldier Study

Steering Wheel Preference Line	The Steering Wheel Preference Line depicts the range of SWPs that can accommodate the driver population. The SWP, an input to the model, should preferably lie on this line.
Seat Track Travel Window (Seat Adjustment)	The Seat Track Travel Window depicts the range of seat track adjustment (fore/aft and up/down), positioned with respect to the AHP, needed to accommodate the desired percentage of the driver population. Seat position is defined as the seat design H-point location after adjustment from the driver (Reed, 2015).
Seat Back Angle	A seat back angle adjustment range that will accommodate the desired fraction of the driver population (Reed, 2015).
Eyellipse	The Eyellipse (a contraction of the words "eye" and "ellipse") depicts the distribution of driver eye locations in the vehicle. Tangents drawn to the Eyellipse determine field-of-view (FOV) used to guide the placement of items such as transparent armor, computer screens, and gauges (Reed, 2015).
Helmet Boundary	The Helmet Boundary depicts the distribution of the driver helmet locations in the vehicle. In this model the Advanced Combat Helmet (ACH) is used. Like the Eyellipse, the Helmet Boundary has a tangent cutoff characteristic and is used to determine or set

	clearances to the vehicle ceiling and nearby equipment (Reed, 2015).
Torso Boundary	The Torso Boundary depicts the forward only distribution of encumbered driver torsos in the vehicle. It has a tangent cutoff characteristic in the horizontal direction. The Abdominal Boundary is used to determine or set steering wheel clearance (Reed, 2015).
Knee Boundary	The Knee Boundary depicts the top, forward, and lateral distributions of resting driver knee locations in the vehicle. The knee boundary is used to assess clearance to the instrument panel (IP), doors, consoles, racks, and any other surrounding components.
Elbow Boundary	The elbow boundary provides the resting elbow location of the occupant. The elbow boundary is used for lateral space claim and to estimate where arms rests should be located (Reed, 2016).
Boundary Manikin Posture and Position	The Boundary Manikin Posture and Position predicts seat position and torso posture for a family of simulated drivers based on the vehicle configuration and the anthropometric inputs of stature, body weight, and erect sitting height (Reed, 2013).

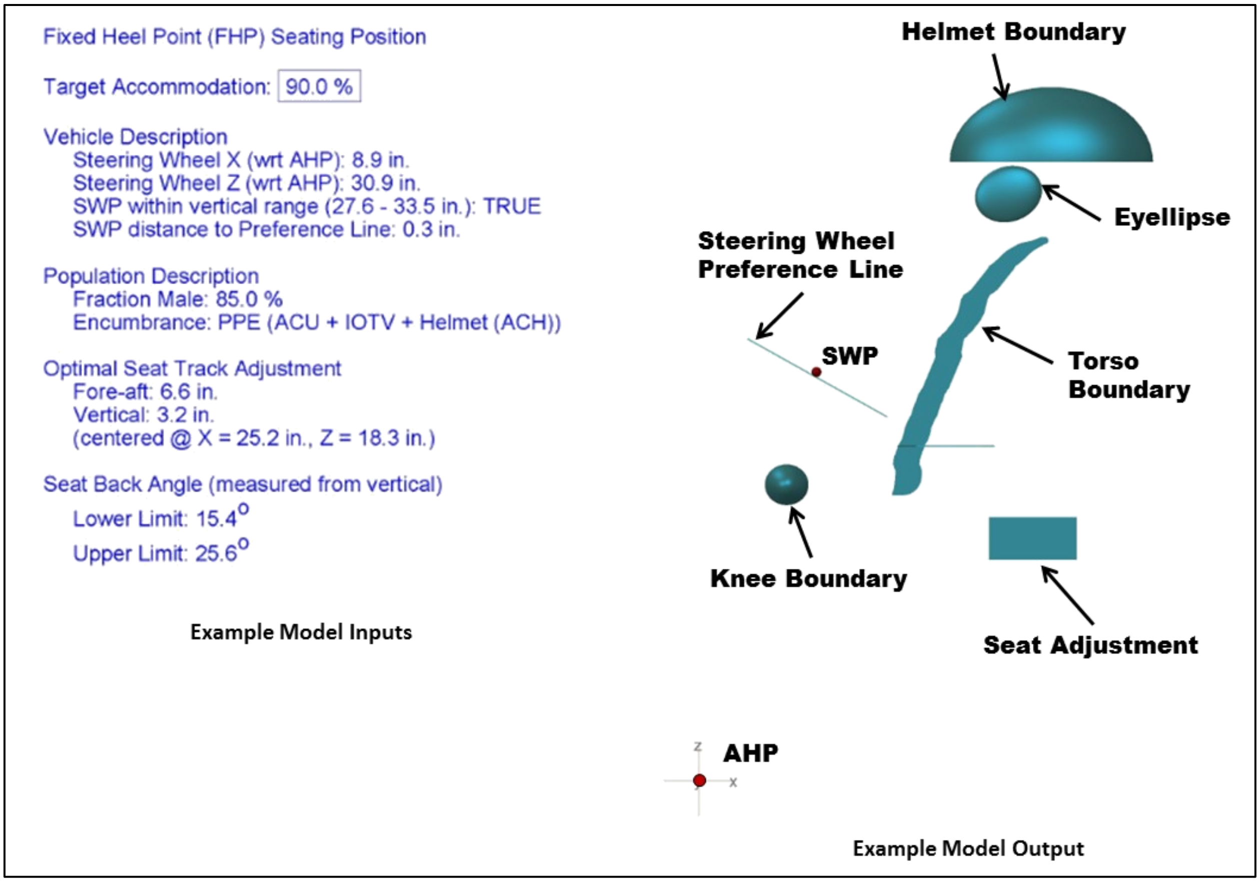

Figure 2: FHP Accommodation Model Example in Creo

2.3.4 Additional Model Outputs – Based on MIL-STD-1472G

Additional outputs of the model include interpretation of MIL-STD-1472G for the vehicle designer to utilize when creating the occupant workspace. Model outputs are described below in Table 3.

Table 3: FHP Accommodation Model Outputs and Definitions based on MIL-STD-1472

Helmet Clearance	The Helmet Clearance represents a 2-inch space claim required above the helmet boundary.
Field of View (FOV) Forward and Lateral	The FOV represents the area where displays or transparent armor would be placed for optimal viewing.
Abdominal Clearance	The Abdominal Clearance represents a 2-inch space claim required for the seated Soldier from the front surface of the Soldier equipment to the steering wheel.
Thigh Clearance	The Thigh Clearance represents a 2-inch space claim required from the top of the thigh of the seated Soldier to the bottom of the steering wheel.

Knee Clearance	The Knee Clearance represents a 2-inch space claim required from the front and top of the knee to any surfaces such as the underside of the IP.

2.4 V&V Scope

The scope of this effort is to V&V a CAD accommodation model for a driver position that utilizes an accelerator pedal and steering wheel. This CAD accommodation model can be applied early in the vehicle design process to ensure accommodation requirements are met and help explore possible design tradeoffs when conflicts with other design parameters exist. The V&V is intended to build confidence in the FHP accommodation model for use in ground vehicle design community.

Verification and validation, per the *Department of Defense Standard Practice Documentation of Verification, Validation, and Accreditation (VV&A) for Models and Simulation* (2008) are defined as follows:

> Verification is the process of determining that a model, simulation, or federation of models and simulations implementations and their associated data accurately represents the developer's conceptual description and specifications.
>
> Validation is the process of determining the degree to which a model, simulation, or federation of models and simulations, and their associated data are accurate representations of the real world from the perspective of the intended use(s).

3. REQUIREMENTS AND ACCEPTABILITY CRITERIA

The FHP accommodation model created in CAD shall meet the requirements shown in Table 4 below.

Table 4: Requirements Relationship Table

#	M&S Requirement	Acceptability Criteria	Metrics/Measures
1	Model allows for a target population input (e.g. 90%) that can be adjusted based on requirements for the vehicle platform	1.1 Target accommodation input option in model	1.1 Representative (Pass) / Non-Representative (Fail)
		1.2 Model outputs adjust with different inputs and matches the UMTRI spreadsheet	1.2 Representative (Pass) / Non-Representative (Fail)
2	Model allows for a population gender mix input (e.g. 85% Male : 15% Female) that can be adjusted based on requirements for the vehicle platform	2.1 Gender mix input option in model	2.1 Representative (Pass) / Non-Representative (Fail)
		2.2 Model outputs adjust with different inputs and Creo model matches the UMTRI spreadsheet	2.2 Representative (Pass) / Non-Representative (Fail)
3	Model allows for ensemble to be selected based on the requirements for the vehicle platform	3.1 Ensemble selection in model	3.1 Representative (Pass) / Non-Representative (Fail)
4		4.1 SWP input option in model	4.1 Representative (Pass) / Non-Representative (Fail)

	Model allows for input of the Steering Wheel Point (SWP) and predicts the Steering Wheel Preference Line	4.2 Model outputs a Steering Wheel Preference Line that matches the UMTRI spreadsheet	4.2 Representative (Pass) / Non-Representative (Fail)
5	Model predicts the expected distribution of driver-selected seat positions relative to the accelerator heel point (AHP) based on the SAE J826 and SIPT seat measurement tools	5.1 Model outputs fore/aft and vertical seat track travel window for a given population and gender mix and matches the UMTRI spreadsheet	5.1 Representative (Pass) / Non-Representative (Fail)
6	Model predicts the dimensions and location of the eyellipse with respect to AHP and mean seat travel	6.1 Model outputs a left and right eyellipse for a given population and gender mix that matches the UMTRI spreadsheet	6.1 Representative (Pass) / Non-Representative (Fail)
7	Model predicts the helmet contour boundary (helmet locations) with respect to the eye location and fitted to the eyellipse	7.1 Model outputs a helmet contour for the given population and gender mix that matches the UMTRI spreadsheet	7.1 Representative (Pass) / Non-Representative (Fail)
8	Model predicts the knee contour based on location of resting drivers' knees in vehicle	8.1 Model outputs a knee ellipsoid for the given population and gender mix that matches the UMTRI spreadsheet	8.1 Representative (Pass) / Non-Representative (Fail)
9	Model predicts elbow contours based on location of resting drivers' elbows in vehicle	9.1 Model outputs elbow contours for the given population and gender mix that matches the UMTRI spreadsheet	9.1 Representative (Pass) / Non-Representative (Fail)
10	Model predicts the forward abdominal boundary	10.1 Model outputs an abdominal boundary for the given population, gender mix, and Soldier equipment configuration that matches the UMTRI spreadsheet	10.1 Representative (Pass) / Non-Representative (Fail)
11	Model provides a clearance zone for the head (helmet) to roof line based on a back calculation from MIL-STD-1472G requirements	11.1 Model output shows a 2" clearance zone from the top of the helmet contour	11.1 Representative (Pass) / Non-Representative (Fail)
12	Model provides vertical and horizontal direct field of view based on MIL-STD-1472G and SAE J1050	12.1 Model output provides a vertical and horizontal direct Field-of-View (FOV) that matches the intent of MIL-STD-1472G and SAE J1050	12.1 Representative (Pass) / Non-Representative (Fail)
13	Model provides a clearance zone for the thigh to steering wheel based on Human Factors requirements	13.1 Model output provides a 2" clearance zone from the top of the thigh of the manikin to the bottom of the steering wheel as measured in side-view	13.1 Representative (Pass) / Non-Representative (Fail)
14	Model provides a clearance zone for the knee to IP or other surfaces based on Human Factors requirements	14.1 Model output provides a 2" clearance zone from the top and front of the knee contour	14.1 Representative (Pass) / Non-Representative (Fail)
15	Model predicts the expected disaccommodation of driver-selected seat positions relative to the accelerator heel point (AHP) if the seat travel is censored	15.1 Model outputs disaccommodation value of a censored seat travel window that matches the UMTRI spreadsheet	15.1 Representative (Pass) / Non-Representative (Fail)

Along with using the FHP accommodation model that is created in CAD, ground vehicle designers will use boundary manikins when creating the interior workspace. The boundary manikins, will be postured and positioned in CAD using the posture prediction model created by UMTRI. The requirement for posture prediction is shown in Table 5 below:

Table 5: Requirements Relationship Table for Boundary Manikins

#	M&S Requirement	Acceptability Criteria	Metrics/Measures
1	Model predicts the location of the hip with respect to the AHP	1.1 Model outputs the location of the hip with respect to the AHP that matches the UMTRI spreadsheet	1.1 Representative (Pass) / Non-Representative (Fail)
		1.2 The manikin hip joint center aligns with the hip point	1.2 Representative (Pass) / Non-Representative (Fail)
2	Model predicts the location of the eye with respect to the AHP	2.1 Model outputs the location of the eye with respect to the AHP that matches the UMTRI spreadsheet	2.1 Representative (Pass) / Non-Representative (Fail)
		2.2 The manikin eye aligns with the eye point	2.2 Representative (Pass) / Non-Representative (Fail)

4. CAPABILITIES, LIMITATIONS, & ASSUMPTIONS (CLA), RISKS/IMPACTS

4.1 M&S Capabilities

The FHP accommodation model will provide the Army and its industry partners with the following M&S capabilities:

- Seat travel and seat back angle positioned in-vehicle
- Relevant population boundaries for Soldier posture in a crew workstation
- Posture prediction for the identified boundary manikins
- Clearances based on interpretation of MIL-STD-1472G
- FOV based on interpretation of MIL-STD-1472G

4.2 M&S Limitations

The FHP accommodation model has limitations based on the ground vehicle requirements for the crew workspace, as follows:

- Predicts fixed heel point driving conditions only (and limited commander positions) and does not address other special driving conditions such as fixed eye point (FEP) or out-of-hatch (OOH).
- Cannot be used if a fixed seat back angle is required for the crew positions.
- Cannot be used if horizontal and vertical seat travel are not integrated into the seat design
- Predicts where the Soldiers ideally wants to posture and position themselves but does not include vehicle limitations such as small transparent armor, low ceiling height, etc.
- Model was created with a specific range of ensemble weights and depths, so it will have to be reevaluated if the ensemble drastically changes in the future.

- Predicts Soldiers' preferred postures and positions but does not take into consideration posture changes due to restricted environments.
- CAD accommodation models serve as a design tool and are not intended to replace, but rather complement, HFE assessment tools.

4.3 M&S Assumptions

The development of a valid FHP accommodation model is based on the following assumptions:

- The fixtures created and used by UMTRI to collect the Soldier data are representative of a tactical vehicle crew workspace.
- Analysis methods used by UMTRI accurately predict Soldier preferred posture and position.
- Position data collected in a static environment over a short period of time are reasonably similar to Soldiers' preferred postures and positions during long-duration driving.

4.4 M&S Risks/Impacts

The constraints and limitations highlighted above could potentially result in an interior workspace design that is not fully optimized. This risk will be mitigated by Subject Matter Experts (SMEs) from Army Research Laboratory (ARL) Human Research and Engineering Directorate (HRED) who complete human factors assessments on the proposed designs, COTS vehicles, and demonstrators during the acquisition process IAW AR 602-2. This assessment will be captured in documentation completed by the ARL HRED SMEs.

5. V&V METHODOLOGY

V&V tasks have been tailored according to need, value added, resources, and funding. The selected tasks address the acceptability criteria outlined in Section 3 of this report. The verification process will establish if UMTRI's data was used correctly to create the CAD model, and the validation process will determine if the model aligns with the real-world environment. The model data will be validated by Subject Matter Expert (SME) CAD reviews and the completion of human factors assessments on one to four COTS vehicles (e.g. FMTV M1083 and HEMTT M977) or ground vehicle demonstrators.

5.1 Planned Data V&V Tasks

Tank Automotive Research, Development, and Engineering Center (TARDEC) Advanced Concepts Team (ACT) is the creator of the FHP CAD accommodation model. TARDEC ACT has minimal Data V&V tasks planned since UMTRI, as the data developer, documented the methods and results of the data collection. The data and statistical techniques employed by UMTRI are appropriate for the creation of the models. Standard anthropometric data was collected on the study participants, and the distributions of important body dimensions were similar to those in ANSUR II data. In addition, a whole-body laser scanner was used to record body shape in both seated and standing posture. Statistical analysis of body landmark data was conducted by UMTRI and validation of the data for the models to predict Soldier posture, as a function of vehicle factors, was completed (Reed, et al, 2013). UMTRI's work has been captured in the following documents:

- UMTRI-2013-13, *Seated Soldier Study: Posture and Body Shape in Vehicle Seats*, Final Report dated October 2013
- UMTRI-2014-26, *Development of Accommodation Models for Soldiers in Vehicles*: *Driver*, Final Report dated September 2014
- UMTRI Excel spreadsheet, *Soldier Driver Accommodation Models 2015-08-29*
- UMTRI Excel spreadsheet, *Seated Soldier Posture Prediction 2013-11-30*

The information provided by UMTRI was used to create the CAD version of the FHP accommodation model. To verify UMTRI's work, TARDEC ACT reviewed each Excel spreadsheet to verify that it aligned with the written reports and then used the information as the basis for the CAD model.

5.2 Planned Model Verification

The CAD accommodation model developer (TARDEC ACT), working with the V&V agent (TARDEC ACT and ARL HRED), will compare the output received in CAD to the output shown in the UMTRI *Soldier Driver Accommodation Models 2015-08-29* Excel spreadsheet and verify that the two correlate. The model input values will be changed to ensure that the helmet boundary, helmet boundary clearance, eyellipse, FOV, abdominal boundary, knee boundary, elbow boundary, seat adjustment, and steering wheel preference line all adjust as expected.

5.2.1 Planned Model Verification Test Run

An audit of the FHP CAD accommodation model will be completed with the M&S proponent, V&V agent, and SMEs. TARDEC ACT will adjust input values of the accommodation model and the team will verify that the outputs previously defined in Table 2 adjust as expected. The test matrix to be used for the verification of the model is shown in Table 6 below:

Table 6: FHP Accommodation Model Test Matrix

Test	Target Accommodation	Steering Wheel Point (AHP Relative to Steering Wheel) L11 (Fore-Aft) X (in.)	Steering Wheel Point (AHP Relative to Steering Wheel) H17 (Vertical) Z (in.)	Fraction Male	Encumbrance	Seat Measurement Tool	Seat Hydration Pack Relief	Comments
1	90%	8.9	30.9	90%	PPE	J826	No	1) Verify Steering Wheel Point (SWP) change adjusts model 2) Check -1472 Clearances 3) Check Direct Vision 4) Check Ground Intercept
2	90%	14.8	30.9	90%	PPE	J826	No	1) Verify SWP change adjusts model
3	90%	13.3	8.9	90%	PPE	SIPT	No	1) Verify SWP change adjusts model 2) Toggle SIPT Offset to verify effect is captured
4	90%	11.8	7.0	90%	PPE	J826	No	1) Verify SWP change adjusts model
5	90%	17.7	27.0	90%	PPE	J826	No	1) Verify SWP change adjusts model 2) Check -1472 Clearances 3) Check Direct Vision 4) Check Ground Intercept
6	90%	17.7	27.0	90%	ACU	J826	No	1) Verify encumbrance impacts model
7	95%	17.7	27.0	90%	ENC	J826	No	1) Verify encumbrance impacts model 2) Test the calculation for accommodation level 3) Check -1472 Clearances 4) Check Direct Vision 5) Check Ground Intercept
8	90%	17.7	27.0	50%	PPE	J826	No	1) Change the gender mix 2) Change encumbrance levels to verify effect is captured 3) Check -1472 Clearances 4) Check Direct Vision 5) Check Ground Intercept
9	90%	17.7	27.0	50%	ACU	J826	No	1) Change the gender mix 2) Change encumbrance levels to verify model changes
10	90%	17.7	27.0	50%	ENC	J826	Yes	1) Change the gender mix 2) Change encumbrance levels to verify model changes 3) Toggle Hydration Pack to verify effect is captured

5.3 Planned Data Collection for Model Validation

The V&V agent and model developer are collaborating to create a research plan to validate the FHP accommodation model. The plan includes gathering posture and position data on Soldiers, spanning a wide range of body sizes, who are qualified to drive ground vehicles. A minimum of 24 Soldiers will be utilized to collect the in-vehicle data. Two or three vehicles will be selected for the study. The intention is to use vehicles with different restriction of the viewing area through the windshield (or transparent armor) to determine if this affects Soldier posture and position.

Data collection includes gathering standard anthropometric data of each Soldier, in-vehicle Soldier posture data, and vehicle measurements. Each Soldier will cycle through all vehicle driver seating conditions while wearing PPE level clothing and equipment per the definition from the *Seated Soldier Study* (2013), i.e., ACU plus IOTV and ACH. Soldier posture will be recorded following driver in-vehicle adjustments before driving and again after driving. Each vehicle will be driven for approximately 10 minutes, with a required stop after five minutes to readjust. A FARO Arm coordinate digitizer will be used to record body landmark locations defining skeletal posture, including hip and eye locations. Reference points on the seat and vehicle will also be recorded (Reed, 2016).

5.4 Planned Data Analysis for Model Validation

The data analysis presented in the draft technical proposal titled *In-Vehicle Data Collection to Validate Soldier Driver Accommodation Models* (2016) has been imported into this section to lay out the plan for data analysis of the model validation.

> The posture and position data will be processed and reduced for comparison with the predictions of the accommodation models developed from the *Seated Soldier Study* (2013). The primary variables of interest are driver eye location, hip location, and driver-selected seat position. Additional analyses of knee, helmet, torso, and elbow locations will be conducted for comparison with the lab-based models.
>
> The analysis will examine three primary metrics: bias, trend, and dispersion. Bias refers to mean differences in responses. For example, if the average driver-selected seat position is further forward in the vehicles than the lab-based data would predict, after accounting for vehicle geometry and body size, that reflects a bias. Trend refers to the effects of body size. For example, the lab data show strong effects of stature on driving posture. Trends between the in-vehicle and laboratory data will be compared. Dispersion refers to the spread in the data, for example the size of the distribution of driver eye locations. This is affected by the trends due to body size but also by residual variance unrelated to Soldier characteristics. The dispersion metrics will be compared to determine if the lab-based models adequately capture the ranges of posture metrics observed in vehicles.
>
> The results of the validation testing may lead to the FHP accommodation model being adjusted to address discrepancies seen between the lab-based model and in-vehicle environment.

5.5 Planned V&V Reporting

The FHP CAD accommodation model V&V effort will produce both a report from the validation test agent and a V&V Report that captures the results of the activities completed per this V&V Plan. Any areas that do not meet the defined V&V acceptability requirements will be reviewed and a path forward will be provided to correct the issue. The V&V Report will be signed off by the developers and V&V SMEs.

6. KEY PARTICIPANTS

Table 7 identifies the participants involved in the VV&A effort including the roles and responsibilities.

Table 7: Key Participants for FHP Accommodation Model VV&A

VV&A Function	Description	Responsible M&S
Accreditation Authority	Organization/individual who approves the use of an M&S for a particular application. The accreditation authority represents the M&S User's interests. The Accreditation Authority is a Government entity.	Director, ARL HRED
Accreditation Agent	Individual, group, or organization designated by the Accreditation Authority to conduct an accreditation assessment for an M&S	ARL HRED / TARDEC ACT
Accreditation Team / Subject Matter Experts (SMEs)	Participants involved in the accreditation effort and individual who, by virtue of education, training, or experience, has expertise in a particular technical or operational discipline, system, or process.	Cheryl A. Burns, ARL HRED David A. Hullinger, ARL HRED TACOM FE Joseph R. Urda, PM-AMPV Frank J. Huston II, TARDEC ACT Gale L. Zielinski, TARDEC ACT Richard W. Kozycki, ARL HRED
M&S Proponent	The organization that has primary responsibility for M&S planning and management that includes development, verification and validation, configuration management, maintenance, use of the model or simulation, and others as appropriate. A Government entity.	Frank J. Huston II, TARDEC ACT Gale. L. Zielinski, TARDEC ACT
M&S User	The individual, group, or organization that uses the results or products from a specific application of the model or simulation.	TARDEC ACT Gale M. Litrichin, TARDEC GSS ARL HRED Government Contractors
Validation Agent	The organization designated by the M&S proponent to perform validation of a model, simulation, or federation of M&S.	Cheryl A. Burns, ARL HRED David A. Hullinger, ARL HRED TACOM FE Joseph R. Urda, PM-AMPV Richard W. Kozycki, ARL HRED
Verification Agent	The organization designated by the M&S proponent to perform verification of a model, simulation, or federation of M&S.	Frank J. Huston II, TARDEC ACT Gale L. Zielinski, TARDEC ACT
M&S Developer	The individual, group or organization responsible for developing or modifying a model or simulation in accordance with a set of design requirements and specifications.	Frank J. Huston II, TARDEC ACT Matthew P. Reed, Ph.D, UMTRI
SMEs	Individual who, by virtue of education, training, or experience, has expertise in a particular technical or operational discipline, system, or process.	Frank J. Huston II, TARDEC ACT Gale L. Zielinski, TARDEC ACT Cheryl A. Burns, ARL HRED Richard W. Kozycki, ARL HRED Brian D. Corner, PhD, MERS - SIAT Joseph L. Parham, NSRDEC Dawn L. Woods, NSRDEC Matthew P. Reed, Ph.D, UMTRI

7. PLANNED V&V RESOURCES

7.1 V&V Resource Requirements

SMEs to support the V&V effort are defined above in Table 7. SMEs are included from Marine Expeditionary Rifle Squad (MERS), ARL HRED, NSRDEC, TARDEC, and UMTRI.

7.2 V&V Milestones and Timeline

The proposed VV&A schedule is provided. Dates may change as the program changes.

Table 8: FHP Accommodation Model VV&A Schedule

Event/ Activity / Milestone (Responsible)	End
Draft Version of FHP CAD Accommodation Model (TARDEC ACT)	1QFY16
Final V&V Plan (TARDEC ACT)	2QFY16
Complete FHP CAD Accommodation Model (TARDEC ACT)	1QFY17
Final V&V Plan Rev A (TARDEC ACT)	2QFY17
FHP CAD Accommodation Model User Guide (TARCED ACT)	2QFY17
Transition FHP CAD Accommodation Model to TARDEC Configuration Management (TARDEC ACT)	3QFY17
Final V&V Report (TARDEC ACT)	1QFY18
Final Accreditation Plan (TARDEC ACT)	2QFY18
Accredit the FHP CAD Accommodation Model (ARL HRED)	2QFY18
Obtain Final Accreditation Approval including Accreditation Report (ARL HRED)	2QFY18

8. Appendices

8.1 Appendix A – References

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8.2 Appendix B – Acronyms

ACH	Advanced Combat Helmet
ACT	Advanced Concepts Team
AHP	Accelerator Heel Point
ANSUR	Army Anthropometric Survey
ARL HRED	Army Research Laboratory Human Research and Engineering Directorate
CAD	Computer-Aided Design
CLA	Capabilities, Limitations, and Assumptions
COTS	Commercial Off-The-Shelf
EMD	Engineering Manufacturing and Development
ENC	Encumbered
ESAPI	Enhanced Small Arms Protective Insert
ESBI	Enhanced Side Ballistic Inserts
FEP	Fixed Eye Point
FHP	Fixed Heel Point
FOV	Field-of-View
HARP	Human Accommodation Reference Point
HSI	Human Systems Integration
IP	Instrument Panel
IOTV	Improved Outer Tactical Vest
MS	Milestone
NSRDEC	Natick Soldier Research Development and Engineering Center
OOH	Out-of-Hatch
PPE	Personal Protective Equipment
SAE	Society of Automotive Engineers
SME	Subject Matter Experts
SWP	Steering Wheel Point
TARDEC	Tank Automotive Research, Development, and Engineering Center
UMTRI	University of Michigan Transportation Research Institute
V&V	Verification and Validation
VV&A	Verification, Validation, and Accreditation

8.3 Appendix C – Distribution List

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